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(54) **HYDRAULIC PUMP/MOTOR**

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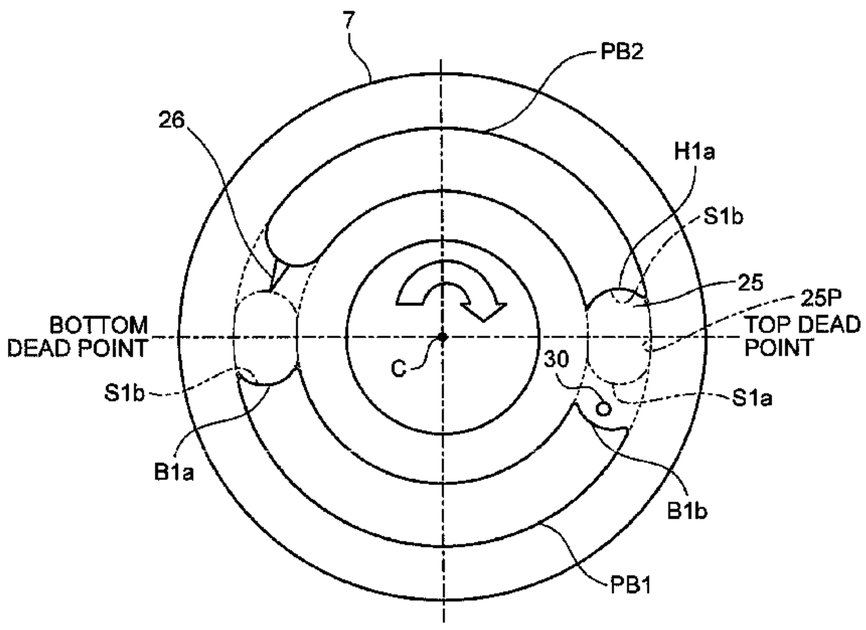
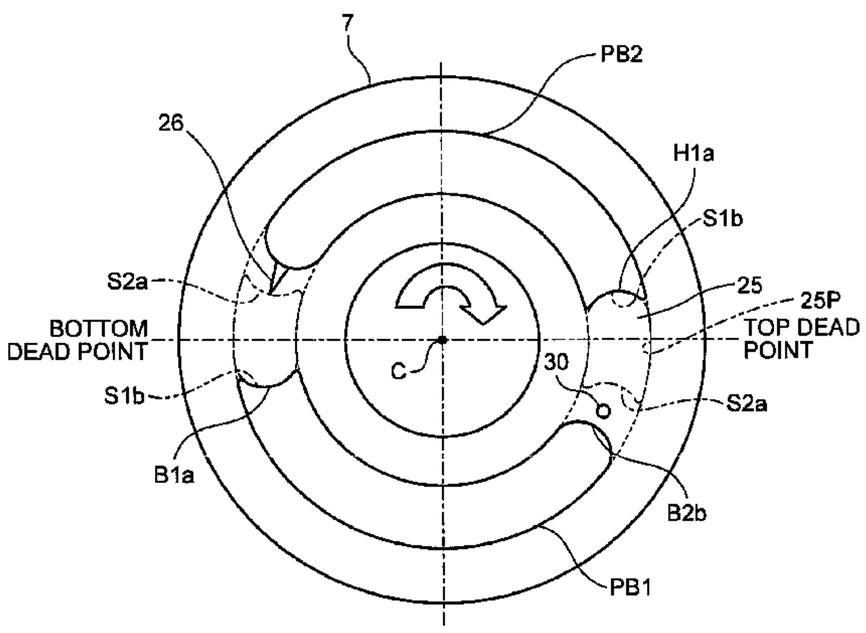
(57) **ABSTRACT**

An axial-type hydraulic pump/motor in which a cylinder block with a plurality of cylinder bores formed around a rotation axis slides with respect to a valve plate that has a valve plate discharge port and a valve plate suction port, and controls the amount of reciprocation of a piston in each cylinder bore depending on the inclination of a swash plate. Based on the rotational direction of the cylinder block, an opening shape of an end portion on the front side in the rotational direction of a cylinder port and an opening shape of an end portion on the rear side in the rotational direction of the valve plate suction port PB1 have the same shape or partially have the same shape.

3 Claims, 10 Drawing Sheets





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F03C 1/34 (2006.01)

(52) **U.S. Cl.**
CPC ***F04B 1/2021*** (2013.01); ***F04B 1/2035*** (2013.01); ***F04B 1/2042*** (2013.01)

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USPC 91/485, 499
See application file for complete search history.

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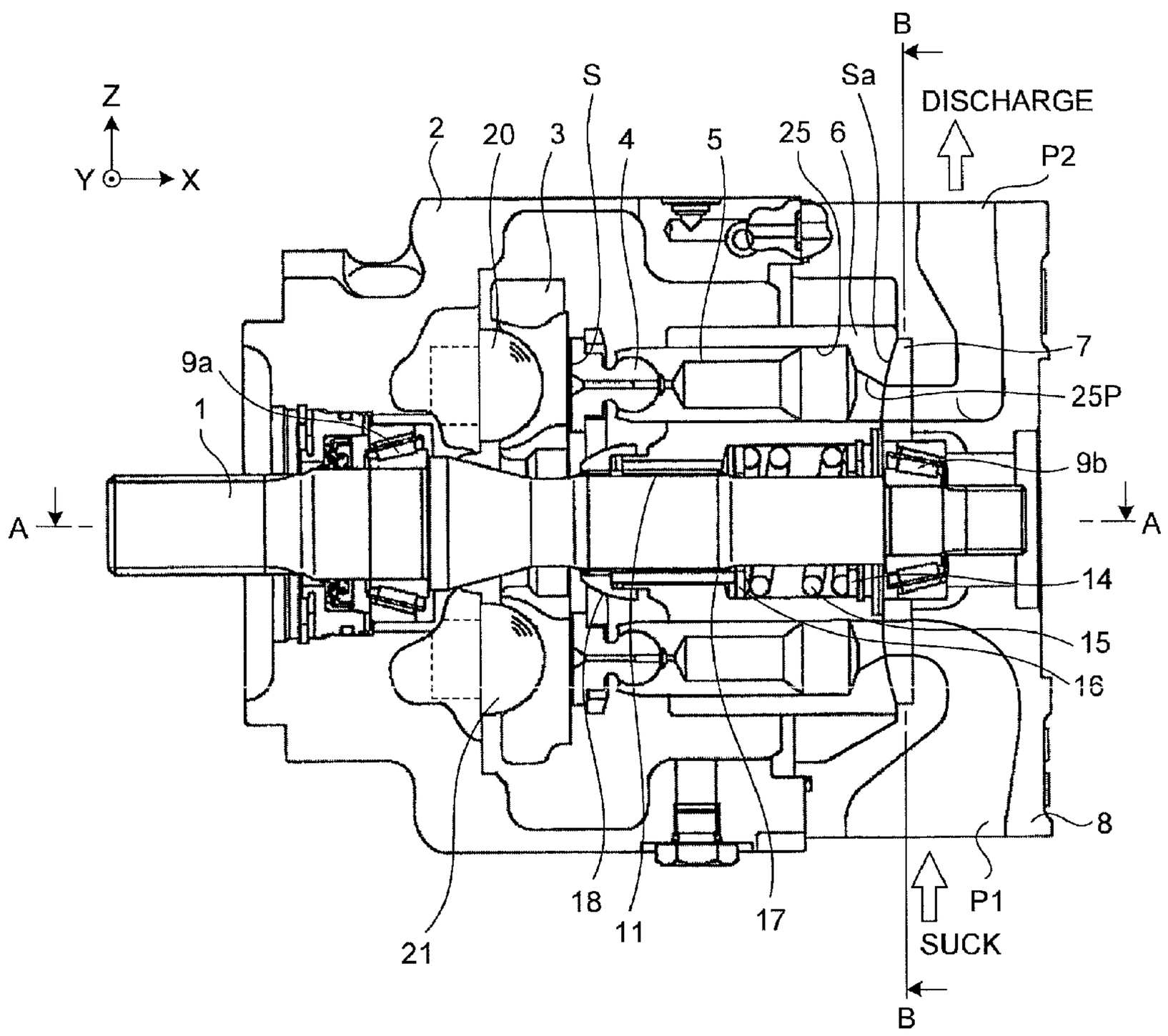
FIG.1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Y
X
B
DISCHARGE
S
Sa
2
20
3
4
5
25
6
P2
7
25P
9a
1
9b
A
A
14
15
16
8
18
11
17
21
P1
SUCK
B

FIG.2

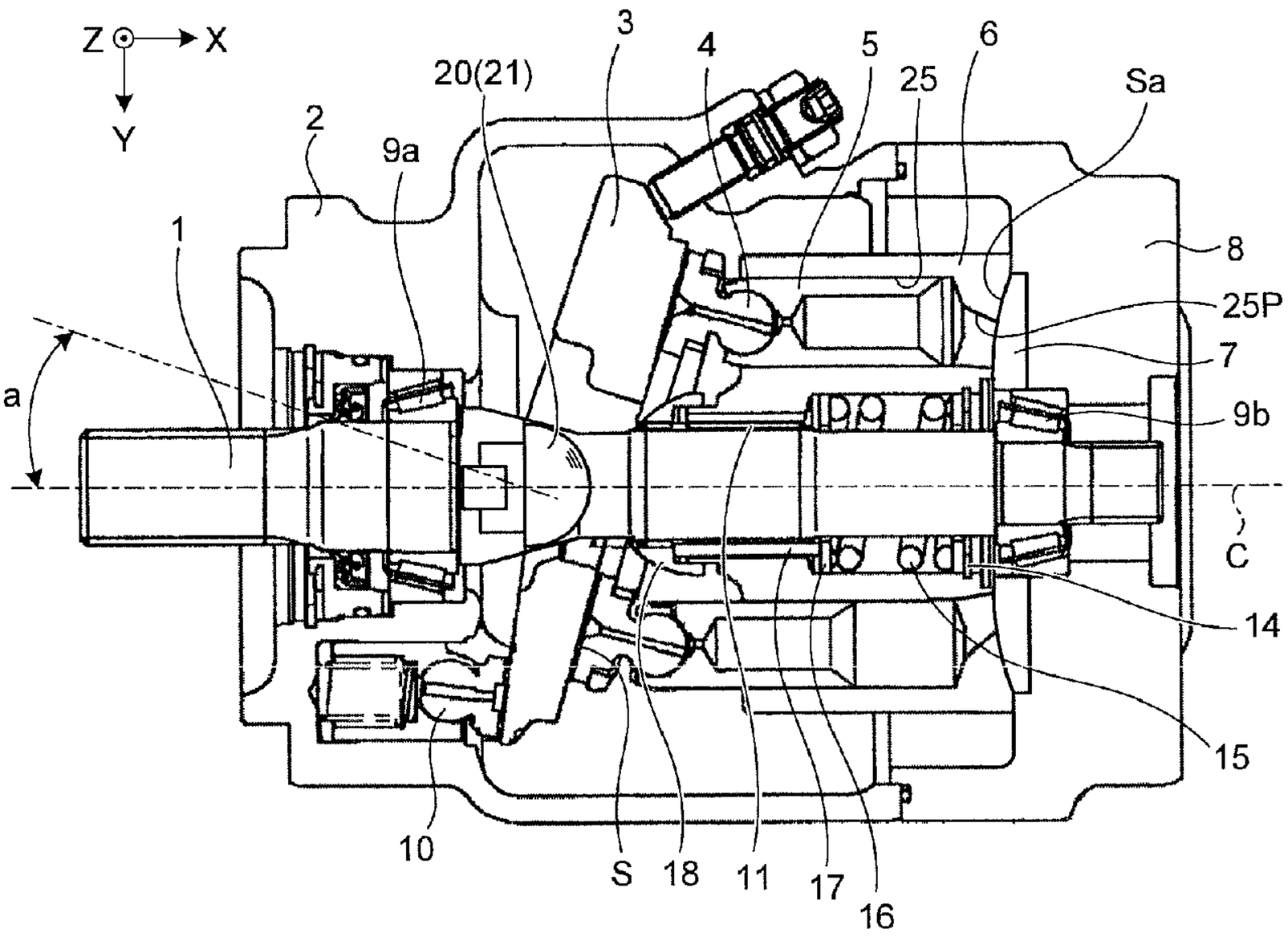


FIG.3

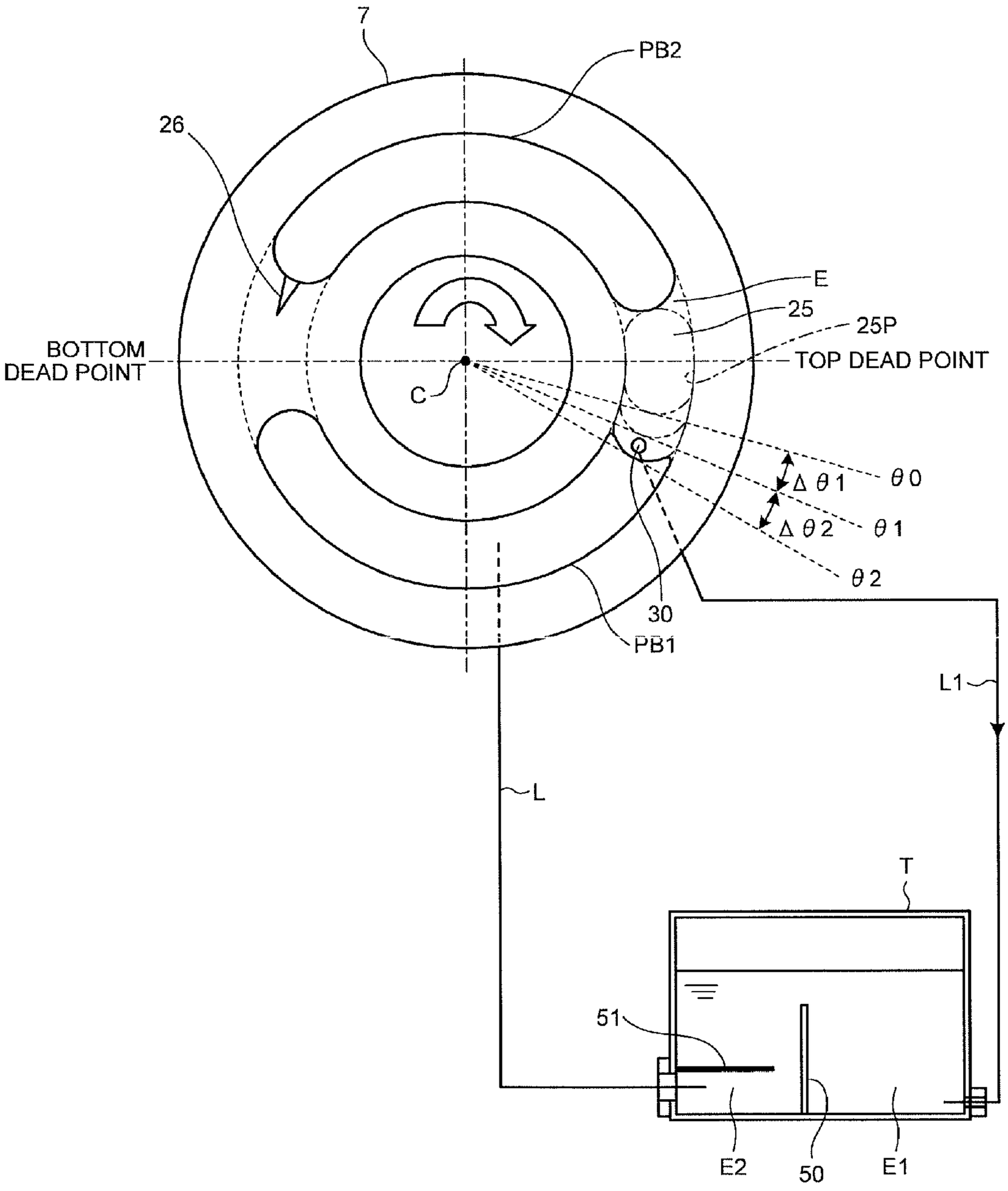
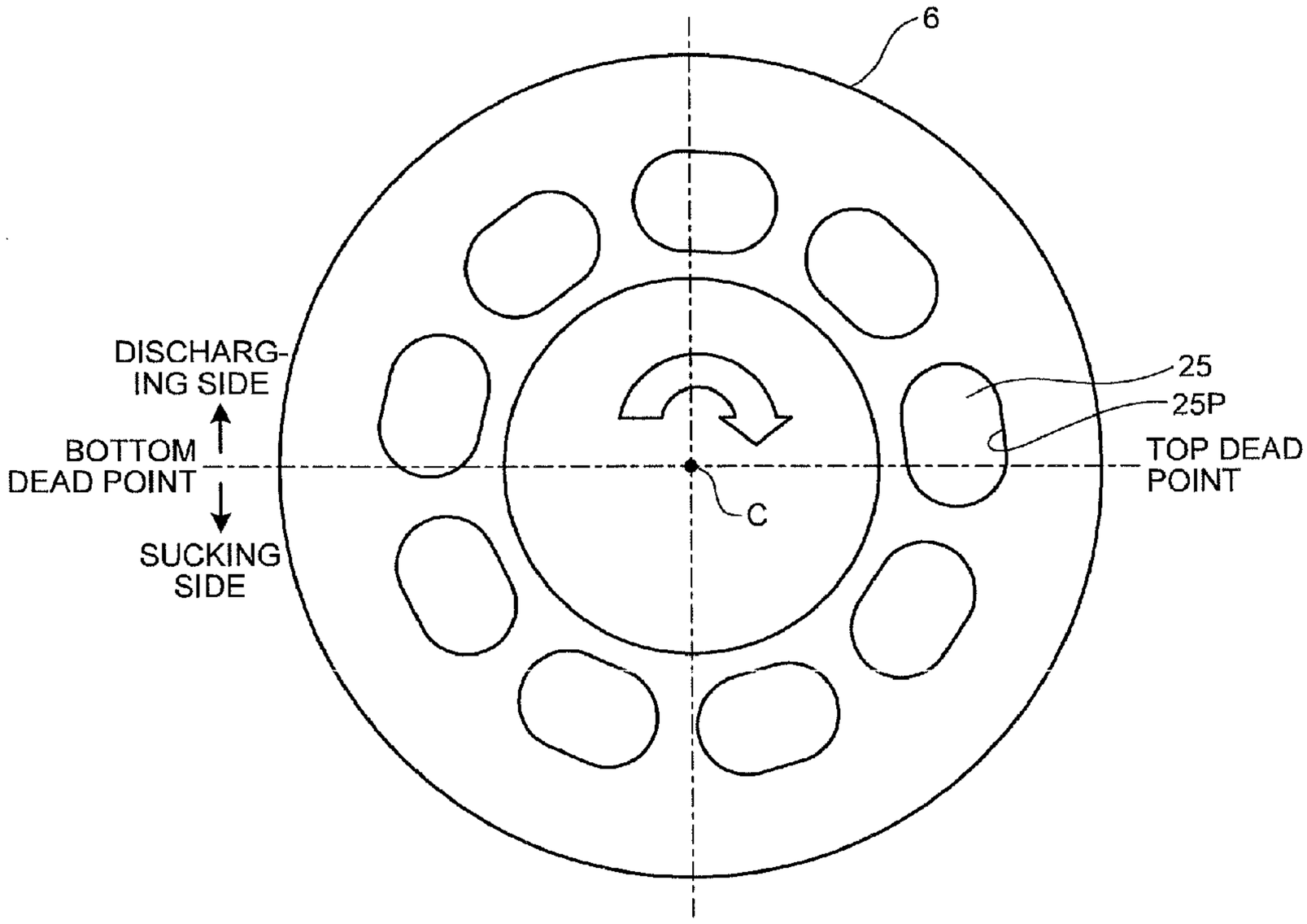

7
PB2
26
E
25
25P
BOTTOM DEAD POINT
TOP DEAD POINT
C
θ0
Δθ1
Δθ2
θ1
θ2
30
PB1
L1
L
T
51
E2
50
E1

FIG.4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ING SIDE
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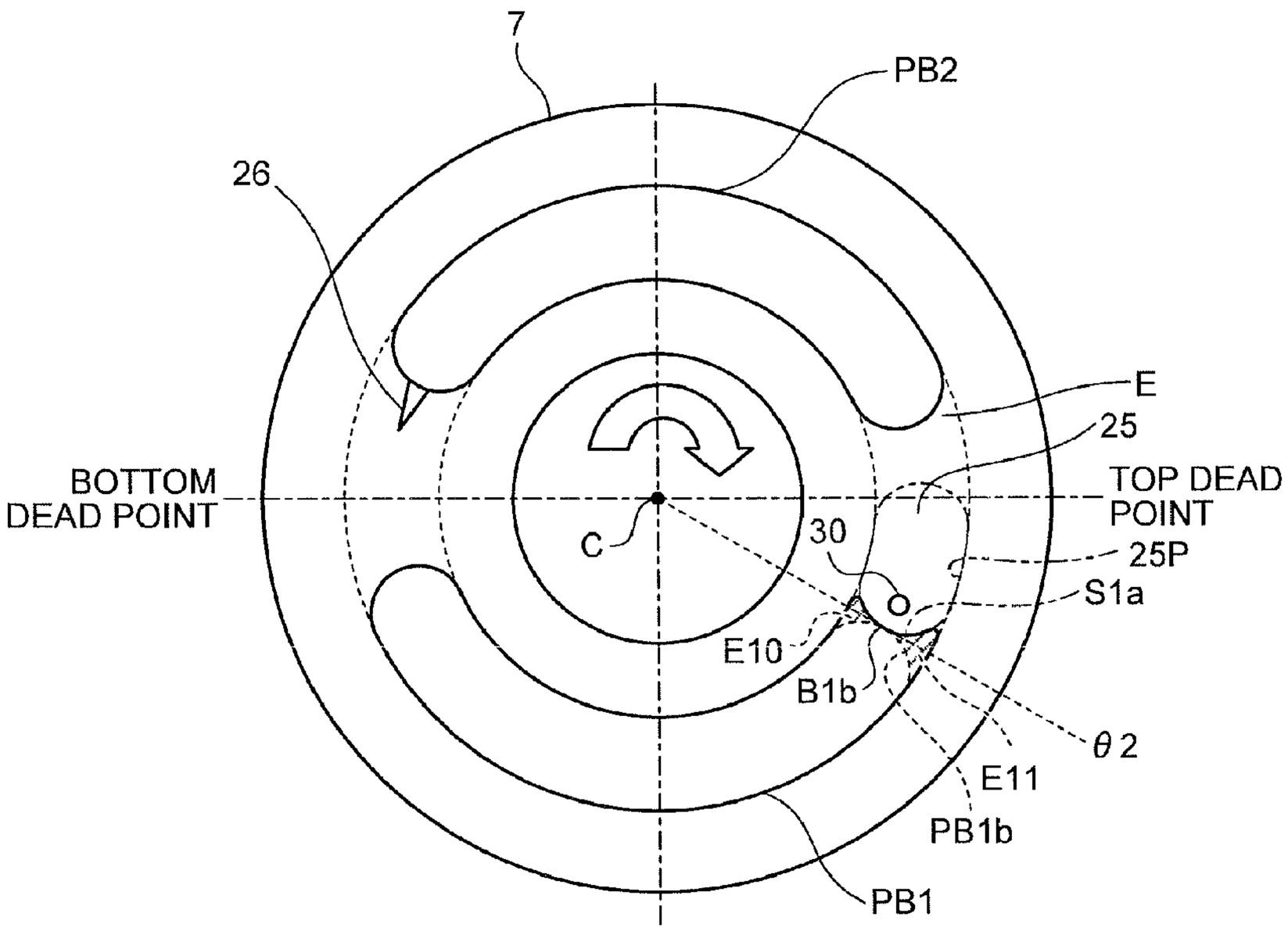
SUCKING
SIDE
25
25P
TOP DEAD
POINT
C

FIG.5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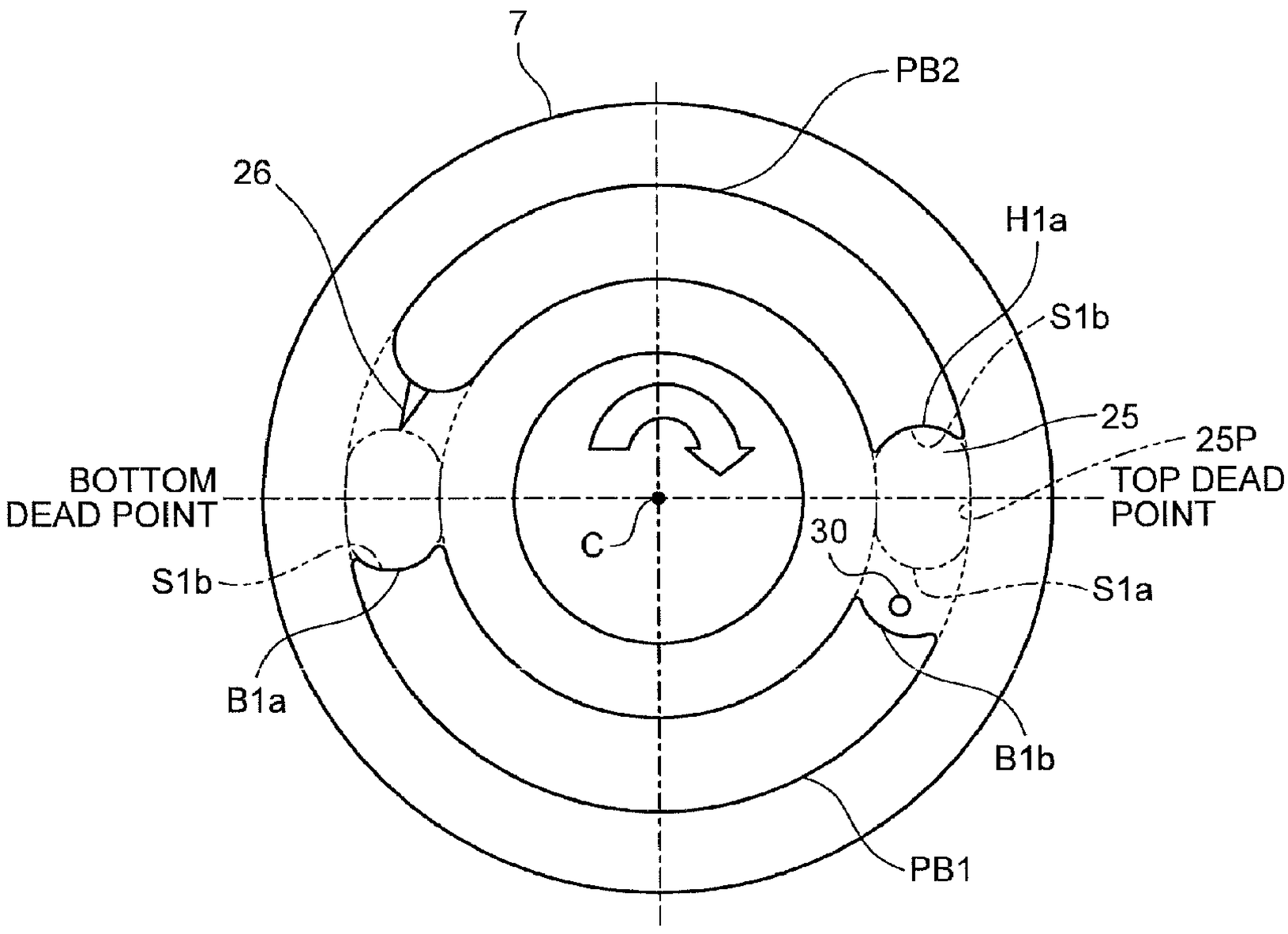
E
25
BOTTOM
DEAD POINT
TOP DEAD
POINT
C
30
25P
S1a
O
E10
B1b
θ2
E11
PB1b
PB1

FIG.6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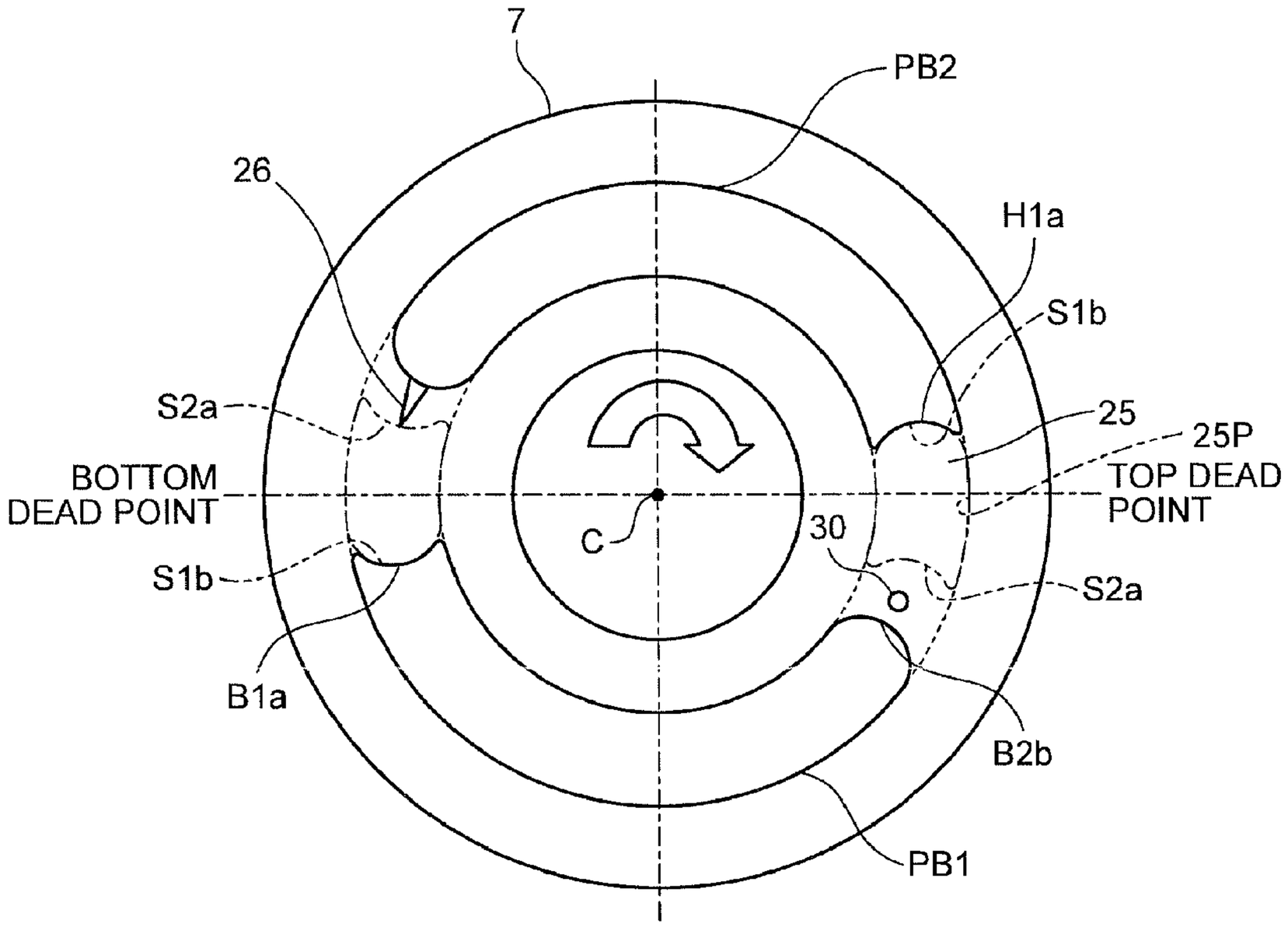
PB2
26
H1a
S1b
25
25P
BOTTOM
DEAD POINT
TOP DEAD
POINT
C
30
S1b
S1a
O
B1a
B1b
PB1

FIG.7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25P
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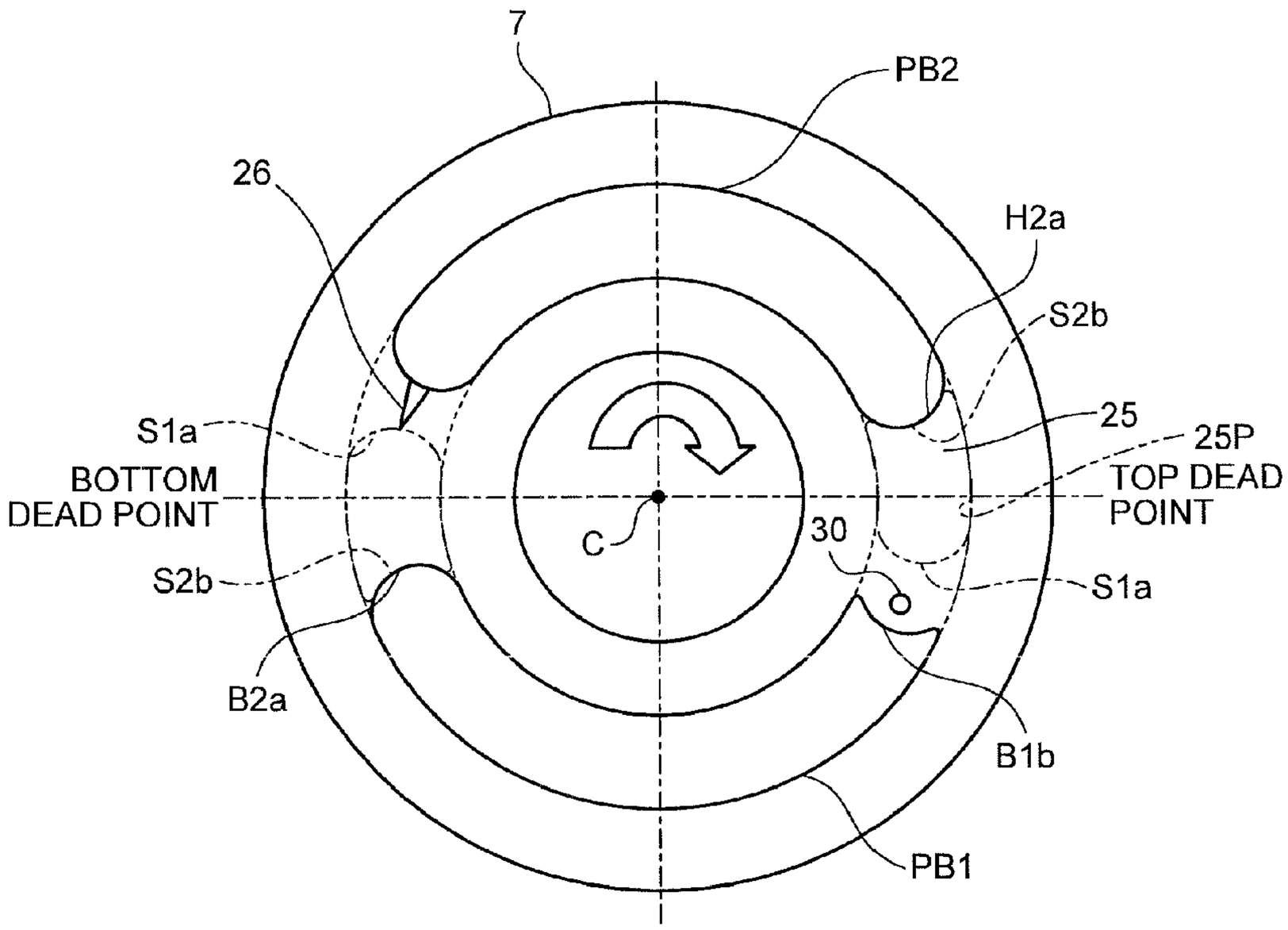
S1b
S2a
B1a
B2b
PB1

FIG.8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S2b
S1a
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25P
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POINT
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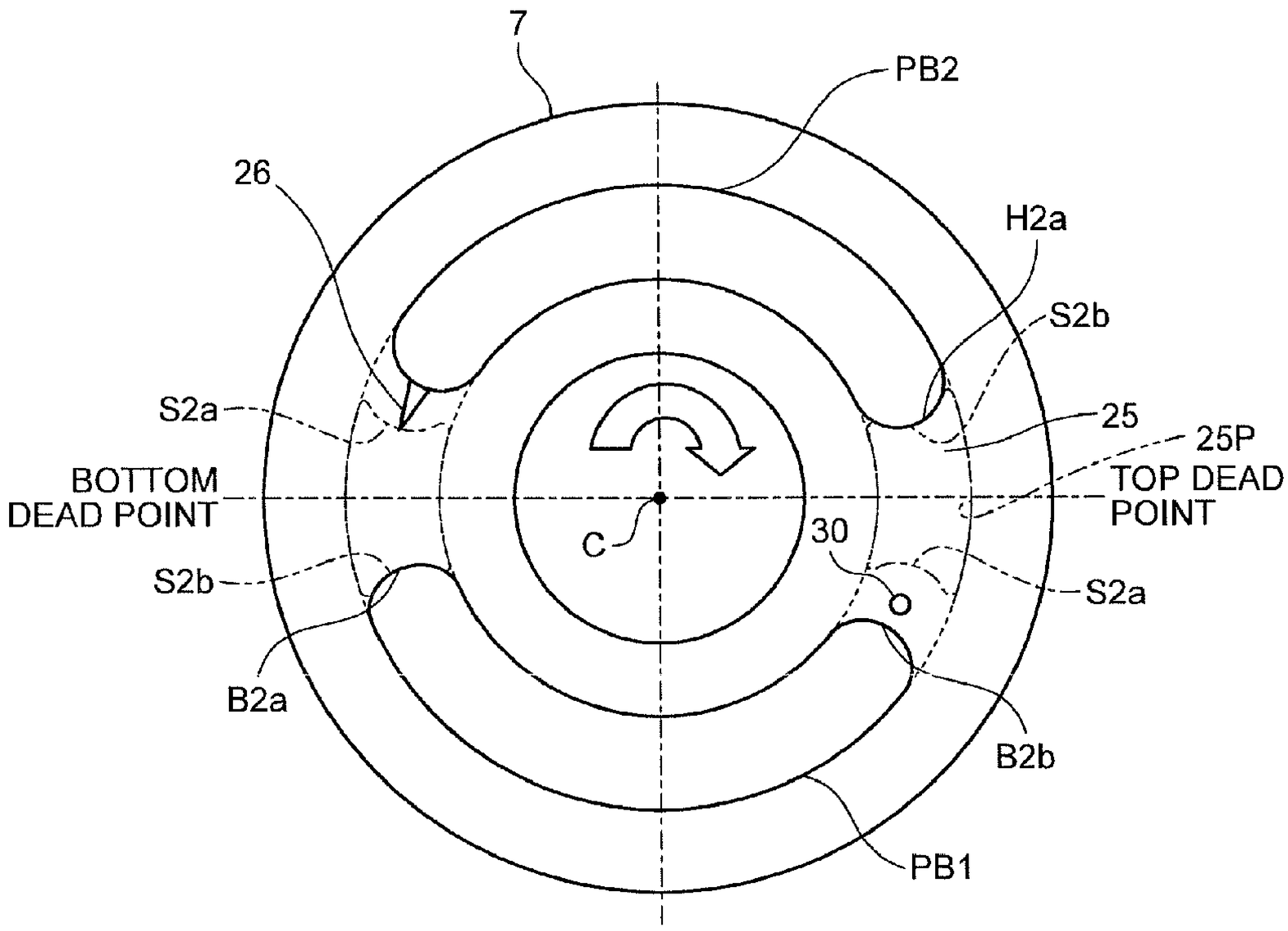
S1a
B2a
B1b
PB1

FIG.9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PB2
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H2a
S2b
S2a
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25P
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DEAD POINT
TOP DEAD
POINT
C
30
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S2b
S2a
B2a
B2b
PB1

FIG.10

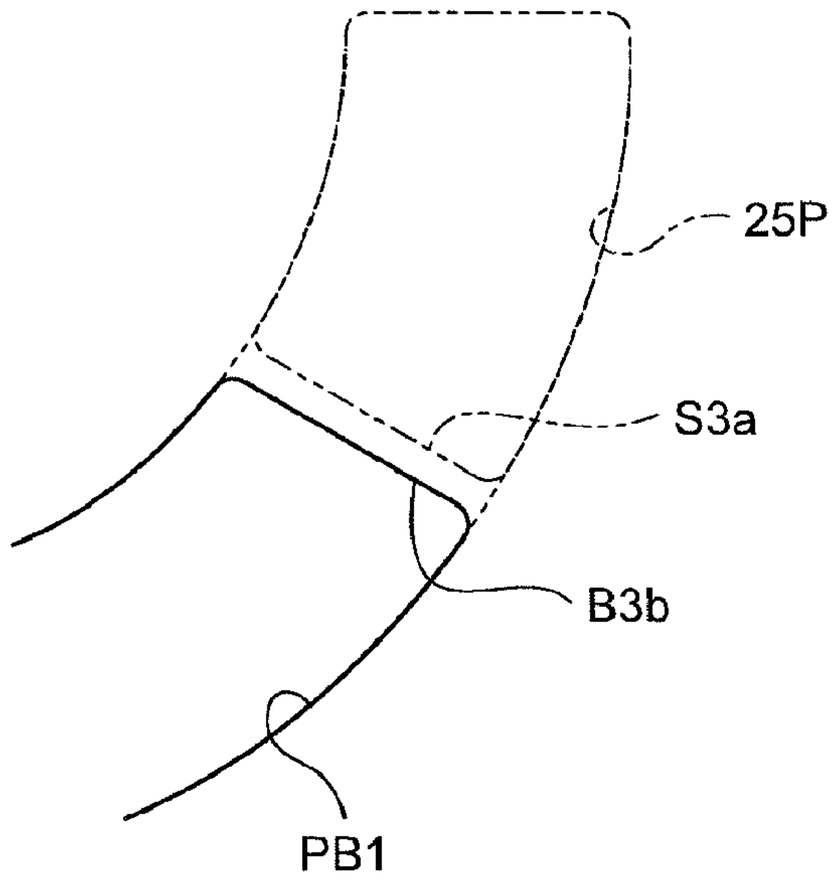
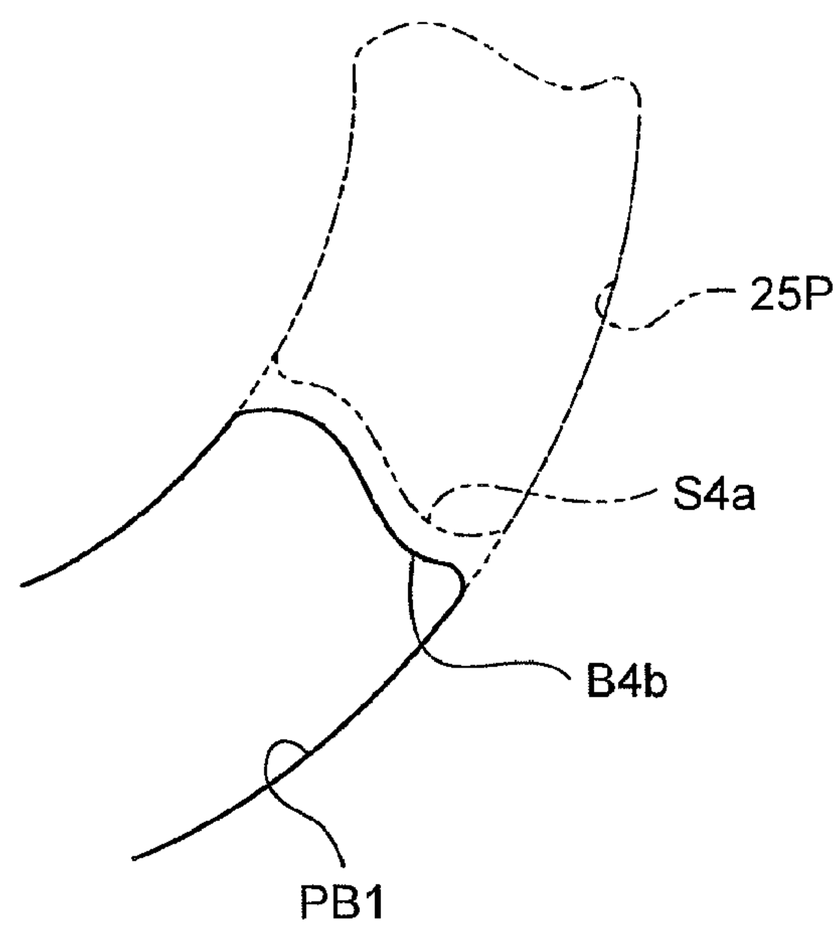


FIG.11



HYDRAULIC PUMP/MOTOR

FIELD

The present invention relates to an axial-type hydraulic pump/motor (hydraulic pump or hydraulic motor) in which a cylinder block with a plurality of cylinder bores formed around a rotation axis slides with respect to a valve plate that has a high-pressure port and a low-pressure port, and controls the amount of reciprocation of a piston in each of the cylinder bores depending on the inclination of a swash plate. In particular, the present invention relates to a hydraulic pump/motor that can suppress a reduction in suction capacity while rotation assistance capability due to a residual pressure inside a cylinder bore is increased when shifting from a discharging process (high-pressure process) to a suction process (low-pressure process).

BACKGROUND

Conventionally, in many cases, an axial-type hydraulic piston pump driven by an engine, and an axial-type hydraulic piston motor driven by a high-pressure working oil are used in construction machines, for example.

For example, the axial-type hydraulic piston pump includes a cylinder block, a plurality of pistons, and a valve plate. The cylinder block is provided so as to rotate integrally with a rotation shaft rotatably provided inside a case and is formed with a plurality of cylinders that are circumferentially apart from each other and extend axially. Each of the pistons is slidably fitted into the corresponding cylinder of the cylinder block, and sucks/discharges a working oil by moving axially in accordance with the rotation of the cylinder block. The valve plate is provided between the case and an end surface of the cylinder block, and is formed with a suction port and a discharge port that communicate with each of the cylinders. In the hydraulic piston pump, when a drive shaft is driven to rotate, the cylinder block, together with a working shaft, rotates inside the case, and each of the pistons reciprocates in the corresponding cylinder of the cylinder block. The working oil sucked into the cylinders from the suction port is pressurized by the pistons, and is discharged from the discharge port as a high-pressure working oil.

When the cylinder port of each cylinder communicates with the suction port of the valve plate, a suction process is performed. In the suction process, the pistons move between the start edge and the end edge of the suction port in a direction projecting from the cylinders, and suck the working oil into the cylinder from the suction port. When the cylinder port of each cylinder communicates with the discharge port, on the other hand, a discharging process is performed. In the discharging process, the pistons move between the start edge and the end edge of the discharge port in a direction entering into the cylinders, and discharge the working oil inside the cylinders into the discharge port. By rotating the cylinder block so as to repeat the suction process and the discharging process, the working oil sucked into the cylinders from the suction port during the suction process is pressurized and discharged to the discharge port during the discharging process.

CITATION LIST

Patent Literature

Patent Literature 1: Japanese Laid-open Patent Publication No. 2000-64950

SUMMARY

Technical Problem

In the conventional hydraulic pump described above or the like, the pressure inside the cylinders, from which the working oil has been discharged via the discharge port of the valve plate during the discharging process, is high.

Therefore, for example, in Patent Literature 1, a residual pressure extraction hole is provided, and causes the high-pressure working oil inside the cylinders to return to the suction port when shifting from the discharging process to the suction process. As a result, a change in the pressure of the working oil from the discharging process to the suction process becomes gentle, and causes the pressure of the working oil inside the cylinder and the pressure of the working oil inside the suction port to be the same when the cylinder port communicates with the suction port.

However, when shifting from the discharging process to the suction process, in a case where a residual pressure inside the cylinder is high, the rotation of the cylinder block is assisted and thus, the rotational efficiency is improved. Therefore, it is preferable that the rotation assist region, which is from a top dead point to the residual pressure extraction hole where the cylinder port communicates with, be increased in length in view of the rotational torque efficiency. However, when the rotation assist region is increased in length, an end portion on the side of the top dead point of the suction port shifts toward the side of a bottom dead point. As a result, the suction starting time at which the cylinder port communicates with the suction port is delayed, and the period of the overall suction process is shortened; therefore, the suction capacity in the suction process is reduced.

The present invention is made in view of the above, and an object thereof is to provide a hydraulic pump/motor that can suppress a reduction in suction capacity while rotation assistance capability due to a residual pressure inside a cylinder bore is increased when shifting from a discharging process to a suction process.

Solution to Problem

To resolve the above-described problem and attain the object, a hydraulic pump/motor according to the present invention is an axial-type hydraulic pump/motor in which a cylinder block with a plurality of cylinder bores formed around a rotation axis slides with respect to a valve plate that has a high-pressure port and a low-pressure port, and controls the amount of reciprocation of a piston in each of the cylinder bores depending on the inclination of a swash plate. Further, opening shapes of the high-pressure port and the low-pressure port extend circumferentially on the same arc centered around the rotation axis, and are annular band shapes that do not include a top dead point and a bottom dead point, an opening shape of a cylinder port in each of the cylinder bores extends circumferentially on the same arc where the high-pressure port and the low-pressure port are disposed, and is an annular band shape that does not communicate with the high-pressure port and the low-pressure port at least when positioned at the top dead point and the bottom dead point, and based on the rotational direction of the cylinder block: an opening shape of an end portion on the front side in the rotational direction of the cylinder port and an opening shape of an end portion on the rear side in the rotational direction of the low-pressure port partially have the same shape; and/or an opening shape of an

end portion on the rear side in the rotational direction of the cylinder port and an opening shape of an end portion on the front side in the rotational direction of the low-pressure port partially have the same shape.

Further, in the hydraulic pump/motor according to the present invention, in the above invention, the opening shape of the end portion on the front side in the rotational direction of the cylinder port and the opening shape of the end portion on the rear side in the rotational direction of the low-pressure port have the same shape, and/or the opening shape of the end portion on the rear side in the rotational direction of the cylinder port and the opening shape of the end portion on the front side in the rotational direction of the low-pressure port have the same shape.

Further, in the hydraulic pump/motor according to the present invention, in the above invention, the opening shape of the end portion on the front side in the rotational direction of the cylinder port and an opening shape of an end portion on the rear side in the rotational direction of the high-pressure port partially have the same shape, and/or the opening shape of the end portion on the rear side in the rotational direction of the cylinder port and an opening shape of an end portion on the front side in the rotational direction of the high-pressure port partially have the same shape.

Further, in the hydraulic pump/motor according to the present invention, in the above invention, the opening shape of the end portion on the front side in the rotational direction of the cylinder port and the opening shape of the end portion on the rear side in the rotational direction of the high-pressure port have the same shape, and/or the opening shape of the end portion on the rear side in the rotational direction of the cylinder port and the opening shape of the end portion on the front side in the rotational direction of the high-pressure port have the same shape.

Further, the hydraulic pump/motor according to the present invention, in the above invention, further includes a residual pressure release port that is provided on the valve plate and communicates with the cylinder bore at the side of the top dead point before the cylinder bore at the side of the top dead point communicates with the low-pressure port. Further, opening portion of the end portion on the rear side in the rotational direction of the low-pressure port is separated from the top dead point so as to communicate with an opening portion of the end portion on the front side in the rotational direction of the cylinder port after the opening portion of the end portion on the front side in the rotational direction of the cylinder port passes a rotation assist region where the rotation of the cylinder block is assisted by a pressure oil inside the cylinder bore from a top dead point position of the cylinder port and a residual pressure release region where the pressure inside the cylinder bore is decreased by the communication between the residual pressure release port and the cylinder bore and to shift to a suction process.

Further, in the hydraulic pump/motor according to the present invention, in the above invention, at least one of an opening portion of the end portion on the front side in the rotational direction of the low-pressure port, an opening portion of the end portion on the rear side in the rotational direction of the high-pressure port, and an opening portion of the end portion on the front side in the rotational direction of the high-pressure port is formed at a position not communicating with the cylinder port only when the cylinder port is positioned at the top dead point or the bottom dead point.

Further, in the hydraulic pump/motor according to the present invention, in the above invention, the opening shape of the cylinder port is a cocoon-like annular band shape in which the end portions on the front side and the rear side in the rotational direction form arcs.

Further, in the hydraulic pump/motor according to the present invention, in the above invention, the opening shapes of the high-pressure port and the low-pressure port are cocoon-like annular band shapes in which the end portions on the front side and the rear side in the rotational directions form arcs.

Further, the hydraulic pump/motor according to the present invention is an axial-type hydraulic pump/motor in which a cylinder block with a plurality of cylinder bores formed around a rotation axis slides with respect to a valve plate that has a high-pressure port and a low-pressure port, and controls the amount of reciprocation of a piston in each of the cylinder bores depending on the inclination of a swash plate. Further, opening shapes of the high-pressure port and the low-pressure port extend circumferentially on the same arc centered around the rotation axis, and are annular band shapes that do not include a top dead point and a bottom dead point, an opening shape of a cylinder port in each of the cylinder bores extends circumferentially on the same arc where the high-pressure port and the low-pressure port are disposed, and is an annular band shape that does not communicate with the high-pressure port and the low-pressure port at least when positioned at the top dead point and the bottom dead point, and based on the rotational direction of the cylinder block: opening shapes of end portions on the front side and the rear side in the rotational direction of the cylinder port are circular convex shapes; opening shapes of end portions on the front side and the rear side in the rotational direction of the high-pressure port and an opening shape of an end portion on the front side in the rotational direction of the low-pressure port are circular convex shapes; an opening shape of an end portion on the rear side in the rotational direction of the low-pressure port is a circular concave shape; and the opening shape of the end portion on the front side in the rotational direction of the cylinder port and the opening shape of the end portion on the rear side in the rotational direction of the low-pressure port have the same shape.

Further, the hydraulic pump/motor according to the present invention is an axial-type hydraulic pump/motor in which a cylinder block with a plurality of cylinder bores formed around a rotation axis slides with respect to a valve plate that has a high-pressure port and a low-pressure port, and controls the amount of reciprocation of a piston in each of the cylinder bores depending on the inclination of a swash plate. Further, opening shapes of the high-pressure port and the low-pressure port extend circumferentially on the same arc centered around the rotation axis, and are annular band shapes that do not include a top dead point and a bottom dead point, an opening shape of a cylinder port in each of the cylinder bores extends circumferentially on the same arc where the high-pressure port and the low-pressure port are disposed, and is an annular band shape that does not communicate with the high-pressure port and the low-pressure port at least when positioned at the top dead point and the bottom dead point, and based on the rotational direction of the cylinder block: opening shapes of end portions on the front side and the rear side in the rotational direction of the cylinder port are circular convex shapes; an opening shape of an end portion on the front side in the rotational direction of the high-pressure port is a circular concave shape; opening shapes of end portions on the front

side and the rear side in the rotational direction of the low-pressure port are circular concave shapes; the opening shape of the end portion on the front side in the rotational direction of the cylinder port and the opening shape of the end portion on the rear side in the rotational direction of the low-pressure port have the same shape; and the opening shape of the end portion on the rear side in the rotational direction of the cylinder port, the opening shape of the end portion on the front side in the rotational direction of the low-pressure port, and the opening shape of the end portion on the front side in the rotational direction of the high-pressure port have the same shape.

Advantageous Effects of Invention

According to the present invention, based on the rotational direction of a cylinder block, an opening shape of an end portion on the front side in the rotational direction of a cylinder port and an opening shape of an end portion on the rear side in the rotational direction of a low-pressure port partially have the same shape, and/or an opening shape of an end portion on the rear side in the rotational direction of the cylinder port and an opening shape of an end portion on the front side in the rotational direction of the low-pressure port partially have the same shape. As a result, an opening area of the low-pressure port becomes large and thus, the reduction in suction capacity can be suppressed while rotation assistance capability due to a residual pressure inside a cylinder bore is increased when shifting from a discharging process to a suction process.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a sectional view illustrating a schematic configuration of a hydraulic pump according to an embodiment of the present invention.

FIG. **2** is a line A-A cross-sectional view of the hydraulic pump illustrated in FIG. **1**.

FIG. **3** is a view illustrating a line B-B cross section of the hydraulic pump illustrated in FIG. **1** and a cross section of a working oil tank connected to the hydraulic pump.

FIG. **4** is a view illustrating a configuration of a sliding surface of a cylinder block with respect to a valve plate when viewed in the −X direction.

FIG. **5** is a view illustrating opening shapes of a valve plate suction port and a valve plate discharge port of the valve plate with respect to a cylinder port illustrated in FIG. **3**.

FIG. **6** is a view illustrating opening shapes of a valve plate suction port and a valve plate discharge port of a valve plate, with respect to a cylinder port, according to a first modification of the embodiment in the present invention.

FIG. **7** is a view illustrating opening shapes of a valve plate suction port and a valve plate discharge port of a valve plate, with respect to a cylinder port, according to a second modification of the embodiment in the present invention.

FIG. **8** is a view illustrating opening shapes of a valve plate suction port and a valve plate discharge port of a valve plate, with respect to a cylinder port, according to a third modification of the embodiment in the present invention.

FIG. **9** is a view illustrating opening shapes of a valve plate suction port and a valve plate discharge port of a valve plate, with respect to a cylinder port, according to a fourth modification of the embodiment in the present invention.

FIG. **10** is a view illustrating an example of an opening shape of a valve plate suction port with respect to a cylinder port according to a fifth modification of the embodiment in the present invention.

FIG. **11** is a view illustrating an example of an opening shape of the valve plate suction port with respect to the cylinder port according to the fifth modification of the embodiment in the present invention.

DESCRIPTION OF EMBODIMENTS

In the following, a hydraulic pump/motor which is an embodiment of the present invention will be described with reference to the drawings.

Embodiment

[Entire Configuration of Hydraulic Pump]

FIG. **1** is a sectional view illustrating a schematic configuration of a hydraulic pump according to a first embodiment of the present invention. FIG. **2** is a line A-A cross-sectional view of the hydraulic pump illustrated in FIG. **1**. The hydraulic pump illustrated in FIGS. **1** and **2** converts the engine speed and the torque transmitted to a shaft **1** to hydraulic pressure and then, discharges oil, sucked in from a suction port P**1**, through a discharge port P**2** as a high-pressure working oil. Furthermore, the hydraulic pump is a variable displacement hydraulic pump that can vary the discharge amount of the working oil from the pump by changing an inclination angle a of a swash plate **3**.

Hereinafter, an axis along an axis C of the shaft **1** is referred to as an X-axis, an axis along an inclined central axis which is a line that connects fulcrums for the swash plate **3** to incline is referred to as a Z-axis, and an axis perpendicular to the X-axis and the Z-axis is referred to as a Y-axis. In addition, the direction from an end portion on an input side of the shaft **1** to an end portion on the opposite side is referred to as the X direction.

The hydraulic pump includes the shaft **1**, a cylinder block **6**, and the swash plate **3**. The shaft **1** is rotatably and pivotally supported by a case **2** and an end cap **8** via bearings **9***a*, **9***b*, respectively. The cylinder block **6** is connected to the shaft **1** via a spline structure **11**, and is driven to rotate integrally with the shaft **1** inside the case **2** and the end cap **8**. The swash plate **3** is provided between a side wall of the case **2** and the cylinder block **6**. The cylinder block **6** is provided with a plurality of piston cylinders (cylinder bores **25**) disposed at equal intervals circumferentially about the axis C of the shaft **1** and in parallel to the axis C of the shaft **1**. A piston **5** capable of reciprocating in parallel to the axis C of the shaft **1** is inserted into each of the plurality of cylinder bores **25**.

The piston **5** that projects from each of the cylinder bores **25** has a spherical concave portion at the tip end thereof. A spherical convex portion of a shoe **4** fits into the spherical concave portion, and the piston **5** and the shoe **4** form a spherical shaft bearing. The spherical concave portion of the piston **5** is caulked and thus, the separation from the shoe **4** is prevented.

The swash plate **3** includes a flat sliding surface S on the side facing the cylinder block **6**. The shoe **4**, in accordance with the rotation of the cylinder block **6** interlocked with the rotation of the shaft **1**, slides circularly or elliptically while being pressed against the sliding surface S. A spring **15**, a movable ring **16**, a needle **17**, and a ring-shaped pressing member **18** are provided around the axis C of the shaft **1**. The spring **15** is supported by a ring **14** provided on the inner periphery of the X direction side of the cylinder block **6**. The movable ring **16** and the needle **17** are pressed by the spring

15. The pressing member **18** abuts on the needle **17**. The shoe **4** is pressed against the sliding surface S by the pressing member **18**.

On the side wall of the case **2**, two hemispherical shaft bearings **20**, **21** each projecting to face the side of the swash plate **3** are provided in symmetrical positions with respect to the axial center of the shaft **1**. On the side of the side wall of the case **2** of the swash plate **3**, two concave spheres are each formed on the portion corresponding to the positions where the shaft bearings **20**, **21** have been disposed. A shaft bearing of the swash plate **3** is formed when the shaft bearings **20**, **21** and two concave spheres of the swash plate **3** abut on each other. The shaft bearings **20**, **21** are disposed in the Z-axis direction.

As illustrated in FIG. **2**, the swash plate **3** inclines in a plane perpendicular to an X-Y plane using a line that connects the shaft bearings **20**, **21** as an axis (parallel to the Z-axis). The inclination of the swash plate **3** is determined by a piston **10** that reciprocates while pressing one end of the swash plate **3** along the

X direction from the side of the side wall of the case **2**. The swash plate **3** inclines, by the reciprocation of the piston **10**, using the line that connects the shaft bearings **20**, **21** as a fulcrum. The sliding surface S also inclines due to the inclination of the swash plate **3** and thus, the cylinder block **6** rotates in accordance with the rotation of the shaft **1**. For example, as illustrated in FIGS. **1** and **2**, in a case where the inclination angle from an X-Z plane is a, when the cylinder block **6** rotates counterclockwise as viewed in the X direction, the shoe **4** slides circularly or elliptically along the sliding surface S and accordingly, the piston **5** inside each of the cylinder bores **25** reciprocates.

When the piston **5** moves to the side of the swash plate **3**, the oil is sucked from a suction port P**1** into each of the cylinder bores **25** via a valve plate **7**. When the piston **5** moves to the side of the valve plate **7**, the oil inside each of the cylinder bores **25** is discharged, via the valve plate **7**, from the discharge port P**2** as a high-pressure working oil. The amount of the working oil discharged from the discharge port P**2** is variably controlled by adjusting the inclination of the swash plate **3**.

[Configuration of Valve Plate and Cylinder Block]

The valve plate **7** fixed to the side of the end cap **8** and the cylinder block **6** which rotates are in contact with each other via a sliding surface Sa. FIG. **3** is a line B-B cross-sectional view of the hydraulic pump illustrated in FIG. **1**. FIG. **4** is a view illustrating a configuration of the sliding surface Sa of the cylinder block **6** with respect to the valve plate **7** when viewed in the −X direction. An end surface on the side of the sliding surface Sa of the valve plate **7** and an end surface on the side of the sliding surface Sa of the cylinder block **6** illustrated in FIGS. **3** and **4** slide over each other by the rotation of the cylinder block **6**.

As illustrated in FIG. **3**, the valve plate **7** includes a valve plate suction port PB**1** that communicates with the suction port P**1**, and a valve plate discharge port PB**2** that communicates with the discharge port P**2**. Opening shapes of the valve plate suction port PB**1** and the valve plate discharge port PB**2** extend circumferentially on the same arc centered around the rotation axis C, and are annular band shapes that do not include a top dead point and a bottom dead point. As illustrated in FIG. **4**, the ports of the nine cylinder bores **25** (cylinder ports **25**P) where the piston **5** reciprocates are provided on the side of the sliding surface Sa of the cylinder block **6** at equal intervals and on the same arc where the valve plate suction port PB**1** and the valve plate discharge port PB**2** are disposed. An opening shape of the cylinder port **25**P extends circumferentially on the same arc where the valve plate suction port PB**1** and the valve plate discharge port PB**2** are disposed, and is an annular band shape that does not communicate with the valve plate suction port PB**1** and the valve plate discharge port PB**2** when positioned at the top dead point and the bottom dead point.

In FIGS. **3** and **4**, when the cylinder block **6** rotates clockwise as viewed in a direction toward the −X direction, as in FIG. **3**, the discharging process is performed on the side of the valve plate discharge port PB**2** which is at the upper side of the drawing, and the suction process is performed on the side of the valve plate suction port PB**1** which is at the lower side of the drawing. Accordingly, in such case, the right end side of the drawing in FIG. **3** becomes the top dead point where the discharging process has switched to the suction process and where the piston **5** has entered maximally to the side of the sliding surface Sa inside the cylinder bore **25**. The high-pressure state inside the cylinder bore **25** shifts to the low-pressure state. On the other hand, the left end side of the drawing in FIG. **3** becomes the bottom dead point where the suction process has switched to the discharging process and where the piston **5** has moved furthest away from the side of the sliding surface Sa inside the cylinder bore **25**. When the cylinder port **25**P passes the bottom dead point, the low-pressure state shifts to the high-pressure state.

As illustrated in FIG. **3**, a notch **26** is provided in the valve plate **7**. The notch **26** is provided so as to extend from the end portion of the valve plate discharge port PB**2** on the side of the bottom dead point to the side of the bottom dead point. The notch **26** has a function of regulating the self-pressure of the cylinder bore **25** before the cylinder bore **25** communicates with the valve plate discharge port PB**2**. By providing the notch **26**, the pressure inside the cylinder bore **25** gradually gets close to the pressure inside the valve plate discharge port PB**2** right before the cylinder bore **25** communicates with the valve plate discharge port PB**2**. Consequently, the erosion and noise of the cylinder bore **25** caused when the cylinder bore **25** communicates with the valve plate discharge port PB**2** are suppressed.

As illustrated in FIG. **3**, a residual pressure release port **30** is provided in the valve plate **7**. The residual pressure release port **30** is provided in a region within a rotational movement region E of the cylinder port **25**P and from the vicinity of the top dead point to the valve plate suction port PB**1**. The residual pressure release port **30** is provided at a position being able to communicate with the cylinder bore **25** before the cylinder bore **25** communicates with the valve plate suction port PB**1**. The residual pressure release port **30** is connected to a working oil tank T via a flow path L**1**. The working oil tank T is connected to the valve plate suction port PB**1** via a flow path L.

The working oil tank T is provided with a partition plate **50** that partitions the working oil into regions E**1**, E**2** in the horizontal direction. The working oil, inside the cylinder bore **25**, which contains a large amount of air flows into the region E**1** via the flow path L**1**. The working oil is supplied from the region E**2** to the valve plate suction port PB**1** via the flow path L. The air in the working oil that has flowed into the region E**1** is removed in the region E**1**. The clean working oil with the air reduced in the region E**1** flows into the region E**2** via the upper portion of the partition plate **50**. In the region E**2**, a shielding plate **51** that extends horizontally is provided at the upper portion of an outlet port for the working oil. By providing the shielding plate **51**, the clean working oil that does not contain settled dust or the like is supplied to the side of the valve plate suction port PB**1**.

From a position where the cylinder port **25**P is at the top dead point, that is, a position where the circumferential tip end of the cylinder port **25**P in the rotation direction is at an angle θ**0**, to a position where the cylinder bore **25** communicates with the residual pressure release port **30** (rotation assist region Δθ**1**), the rotation of the cylinder block **6** is assisted by the compressed working oil inside the cylinder bore **25**. Conventionally, the working oil in the suction port P**1** is assisted using an impeller (not illustrated) that uses the rotational force of the shaft **1**; however, depending on the types of devices, there is a case where the impeller does not have to be used by performing the rotation assist. Therefore, by performing the rotation assist as much as possible, energy efficiency can be improved while the structure becomes simple.

Thereafter, until the circumferential tip end of the cylinder port **25**P passes an angle θ**1** and the cylinder bore **25** communicates with the residual pressure release port **30**, and the cylinder bore **25** communicates with the valve plate suction port PB**1** when the circumferential tip end of the cylinder port **25**P is at an angle θ**2** (residual pressure release region Δθ**2**), the compressed working oil inside the cylinder bore **25** flows into the working oil tank T via the residual pressure release port **30** and the flow path L**1**. As a result, a residual pressure inside the cylinder bore **25** is decreased.

[Opening Shapes of Cylinder Port and Valve Plate Suction Port]

As illustrated in FIG. **5**, an opening shape PB**1***b* of an end portion on the rear side in the rotational direction of a conventional valve plate suction port PB**1** has an arc projecting toward the rear end side. Similarly, an opening shape S**1***a* of an end portion on the front side in the rotational direction of the cylinder port **25**P has an arc projecting toward the tip end side. Therefore, when the cylinder port **25**P communicates with the valve plate suction port PB**1** at the angle θ**2**, they contact each other at a point and the communicating area has been enlarged gradually in accordance with the rotation of the cylinder block **6**.

In the present embodiment, the opening shape PB**1***b* of the end portion on the rear side in the rotational direction of the valve plate suction port PB**1** is an opening shape B**1***b* of an end portion on the rear side in the rotational direction thereof. In addition, the opening shape B**1***b* of the end portion on the rear side in the rotational direction and the opening shape S**1***a* of the end portion on the front side in the rotational direction have the same shape. That is, when the cylinder port **25**P communicates with the valve plate suction port PB**1** in accordance with the rotation of the cylinder block **6**, the opening shape S**1***a* of the end portion on the front side in the rotational direction of the cylinder port **25**P and the opening shape B**1***b* of the end portion on the rear side in the rotational direction of the valve plate suction port PB**1** overlap. As a result, in comparison with the past, the suction capacity in the suction process can be increased by the area of regions E**10**, E**11** illustrated by diagonal lines. That is, it is possible to suppress the reduction in suction capacity even if the rotation assist region Δθ**1** is set larger in comparison with the past.

When the cylinder port **25**P communicates with the valve plate suction port PB**1**, the opening shape B**1***b* of the end portion on the rear side in the rotational direction of the valve plate suction port PB**1** and the opening shape S**1***a* of the end portion on the front side in the rotational direction of the cylinder port **25**P may partially have the same shape and partially overlap.

Both end portions in the radial direction of the opening shape B**1***b* of the end portion on the rear side in the rotational direction of the valve plate suction port PB**1** are chamfered by the end mill processing.

(First Modification)

In the embodiment described above, the opening shape Bib of the end portion on the rear side in the rotational direction of the valve plate suction port PB**1** and the opening shape S**1***a* of the end portion on the front side in the rotational direction of the cylinder port **25**P have the same shape. As illustrated in FIG. **6**, in a first modification, an opening shape B**1***a* of an end portion on the front side in the rotational direction of a valve plate suction port PB**1** and an opening shape H**1***a* of an end portion on the front side in the rotational direction of a valve plate discharge port PB**2** each have the same shape as an opening shape Sib of an end portion on the rear side in the rotational direction of a cylinder port **25**P. That is, when the communication between the cylinder port **25**P and the valve plate suction port PB**1** is cut off in accordance with the rotation of the cylinder block **6**, and when the communication between the cylinder port **25**P and the valve plate discharge port PB**2** is cut off, the opening shape S**1***b* of the end portion on the rear side in the rotational direction of the cylinder port **25**P overlaps an opening shape B**1***a* of am end portion on the front side in the rotational direction of the valve plate suction port PB**1** and an opening shape H**1***a* of an end portion on the front side in the rotational direction of the valve plate discharge port PB**2**. As a result, the suction area and the discharge area can be larger than in the past.

When the communication between the cylinder port **25**P and the valve plate suction port PB**1** is cut off, the opening shape B**1***a* of the end portion on the front side in the rotational direction, the opening shape H**1***a* of the end portion on the front side in the rotational direction, and the opening shape S**1***b* of the end portion on the rear side in the rotational direction may partially be the same, and the opening shape B**1***a* and the opening shape H**1***a* may each partially overlap the opening shape S**1***b*. The opening shape B**1***a* of the end portion on the front side in the rotational direction or the opening shape H**1***a* of the end portion on the front side in the rotational direction may be the same or partially be the same as the opening shape S**1***b* of the end portion on the rear side in the rotational direction.

As illustrated in FIG. **6**, in order to enlarge the suction area and the discharge area as described above, it is preferable that the opening areas of the valve plate suction port PB**1** and the valve plate discharge port PB**2** be widened as much as possible so that the cylinder port **25**P does not communicate with the valve plate suction port PB**1** and the valve plate discharge port PB**2** only when the cylinder port **25**P is positioned at a top dead point and a bottom dead point. However, a circumferential rear end opening position of the valve plate suction port PB**1** that includes a rotation assist region Δθ**1** where a discharging process is shifted to a suction process is not limited to this. In a case where a notch **26** is provided on the valve plate discharge port PB**2**, the cylinder port **25**P does not communicate with the tip end portion of the notch **26** only when the cylinder port **25**P is positioned at the bottom dead point. The opening areas of the valve plate suction port PB**1** and the valve plate discharge port PB**2** are widened as much as possible so that the cylinder port **25**P does not communicate with the valve plate suction port PB**1** and the valve plate discharge port PB**2** only when the cylinder port **25**P is positioned at the top dead point and the bottom dead point; however, in consideration of

manufacturing errors, it is preferable to separately position the ports PB**1** and PB**2** at a predetermined margin.

(Second Modification)

According to a second modification, as illustrated in FIG. **7**, the convex opening shape S**1***a* of the end portion on the front side in the rotational direction of the cylinder port **25**P is changed to a concave opening shape S**2***a* of an end portion on the front side in the rotational direction, and the concave opening shape B**1***b* of the end portion on the rear side in the rotational direction of the valve plate suction port PB**1** is changed to a convex opening shape B**2***b* of an end portion on the rear side in the rotational direction of a valve plate suction port PB**1**; therefore, the opening shape S**2***a* of the end portion on the front side in the rotational direction and the opening shape B**2***b* of the end portion on the rear side in the rotational direction have the same shape. That is, when a cylinder port **25**P communicates with the valve plate suction port PB**1** in accordance with the rotation of a cylinder block **6**, the opening shape S**2***a* of the end portion on the front side in the rotational direction of the cylinder port **25**P and the opening shape B**2***b* of the end portion on the rear side in the rotational direction of the valve plate suction port PB**1** overlap. Similar to the first modification, when the communication between the cylinder port **25**P and the valve plate suction port PB**1** is cut off, and when the communication between the cylinder port **25**P and the valve plate discharge port PB**2** is cut off, an opening shape S**1***b* of an end portion on the rear side in the rotational direction of the cylinder port **25**P overlaps an opening shape B**1***a* of an end portion on the front side in the rotational direction of the valve plate suction port PB**1** and an opening shape H**1***a* of an end portion on the front side in the rotational direction of the valve plate discharge port PB**2**. Also in this case, the opening shape S**2***a* of the end portion on the front side in the rotational direction and the opening shape B**2***b* of the end portion on the rear side in the rotational direction may partially be the same.

(Third Modification)

According to a third modification, as illustrated in FIG. **8**, an opening shape of an end portion on the front side in the rotational direction of a cylinder port **25**P is a convex opening shape S**1***a* of the end portion on the front side in the rotational direction, and an opening shape of an end portion on the rear side in the rotational direction of the cylinder port **25**P is a concave opening shape S**2***b* of the end portion on the rear side in the rotational direction. Accordingly, an opening shape of an end portion on the rear side in the rotational direction of a valve plate suction port PB**1** is a concave opening shape B**1***b* of the end portion on the rear side in the rotational direction, an opening shape of an end portion on the front side in the rotational direction of the valve plate suction port PB**1** is a convex opening shape B**2***a* of the end portion on the front side in the rotational direction, and an opening shape of an end portion on the front side in the rotational direction of a valve plate discharge port PB**2** is a convex opening shape H**2***a* of the end portion on the front side in the rotational direction. Furthermore, the opening shape S**1***a* of the end portion on the front side in the rotational direction and the opening shape B**1***b* of the end portion on the rear side in the rotational direction have the same shape. The opening shape S**2***b* of the end portion on the rear side in the rotational direction and the opening shape B**2***a* of the end portion on the front side in the rotational direction have the same shape. The opening shape S**2***b* of the end portion on the rear side in the rotational direction and the opening shape H**2***a* of the end portion on the front side in the rotational direction have the same shape. That is, when the cylinder port **25**P communicates with the valve plate suction port PB**1** and when the communication therebetween is cut off, and when the communication between the cylinder port **25**P and the valve plate discharge port PB**2** is cut off, one opening shape of the end portion in the port overlaps the other. Also in this case, the opening shapes may not have completely the same shape, but may partially have the same shape.

(Fourth Modification)

According to a fourth modification, as illustrated in FIG. **9**, an opening shape of an end portion on the front side in the rotational direction of a cylinder port **25**P and an opening shape of an end portion on the rear side in the rotational direction of the cylinder port **25**P are a concave opening shape S**2***a* of the end portion on the front side in the rotational direction and a concave opening shape S**2***b* of the end portion on the rear side in the rotational direction, respectively. Accordingly, an opening shape B**2***b* of an end portion on the rear side in the rotational direction of a valve plate suction port PB**1** has a convex shape, an opening shape B**2***a* of an end portion on the front side in the rotational direction of the valve plate suction port PB**1** has a convex shape, and an opening shape H**2***a* of an end portion on the front side in the rotational direction of a valve plate discharge port PB**2** has a convex shape. Furthermore, the opening shape S**2***a* of the end portion on the front side in the rotational direction and the opening shape B**2***b* of the end portion on the rear side in the rotational direction have the same shape. The opening shape S**2***b* of the end portion on the rear side in the rotational direction and the opening shape B**2***a* of the end portion on the front side in the rotational direction have the same shape. The opening shape S**2***b* of the end portion on the rear side in the rotational direction and the opening shape H**2***a* of the end portion on the front side in the rotational direction have the same shape. That is, when the cylinder port **25**P communicates with the valve plate suction port PB**1** and when the communication therebetween is cut off, and when the communication between the cylinder port **25**P and the valve plate discharge port PB**2** is cut off, one opening shape of the end portion in the port overlaps the other. Also in this case, the opening shapes may not have completely the same shape, but may partially have the same shape

(Fifth Modification)

In the embodiment and first to fourth modifications described above, the opening shapes of the end portions on the front side and/or the rear side in the rotational direction have been circular convex shapes or circular concave shapes; however, the opening shapes of the end portions are not limited to these, and may be of any shape. For example, each opening shape may have the same shape with a straight line shape as an opening shape S**3***a* of an end portion on the front side in the rotational direction of a cylinder port **25**P and an opening shape B**3***b* of an end portion on the rear side in the rotational direction of a valve plate suction port PB**1** illustrated in FIG. **10**. In addition, each opening shape may have the same shape with a wave shape having a convex/concave shape as an opening shape S**4***a* of an end portion on the front side in the rotational direction of the cylinder port **25**P and an opening shape B**4***b* of an end portion on the rear side in the rotational direction of the valve plate suction port PB**1** illustrated in FIG. **11**. Also in these cases, the shapes may not have completely the same shape, but may partially have the same shape.

The convex shape or concave shape of the opening shape in the embodiment and first to fourth modifications described above includes an inverted U-shape or a U-shape, respectively.

The components of the embodiment and first to fifth modifications described above can be combined as appropriate.

In the embodiment and first to fifth modifications described above, the hydraulic pump has been described as an example; however, the invention is not limited to this, and can also be applied to a hydraulic motor. In the case of the hydraulic motor, a high-pressure side corresponds to a discharge side of the hydraulic pump, and a low-pressure side corresponds to a suction side of the hydraulic pump.

Also in this case, in accordance with the rotation of a cylinder block **6**, when a cylinder port **25**P communicates with a low-pressure port or when the communication therebetween is cut off, or when the communication between the cylinder port **25**P and a high-pressure port is cut off, each opening shape of the end portion in the rotational direction in the port completely or partially overlaps.

Furthermore, in the embodiment and first to fifth modifications, the swash plate-type hydraulic pump/motor has been described as an example; however, the invention is not limited to this, and can also be applied to an inclined shaft-type hydraulic pump/motor.

REFERENCE SIGNS LIST

1 Shaft
2 Case
3 Swash plate
4 Shoe
5, **10** Piston
6 Cylinder block
7 Valve plate
8 End cap
9*a*, **9***b* Bearing
11 Spline structure
14 Ring
15 Spring
16 Movable ring
17 Needle
18 Pressing Member
20, **21** Shaft bearing
25 Cylinder bore
25P Cylinder port
26 Notch
30 Residual pressure release port
50 Partition plate
51 Shielding plate
L, L**1** Flow path
P**1** Suction port
P**2** Discharge port
PB**1** Valve plate suction port
PB**2** Valve plate discharge port
S, Sa Sliding surface
S**1***a*, S**2***a*, S**3***a*, S**4***a* Opening shape of end portion on rear side in rotational direction of cylinder port
S**1***b*, S**2***b* Opening shape of end portion on rear side in rotational direction of cylinder port
B**1***a*, B**2***a* Opening shape of end portion on front side in rotational direction of valve plate suction port
B**1***b*, B**2***b*, B**3***b*, B**4***b* Opening shape of end portion on rear side in rotational direction of valve plate suction port
H**1***a*, H**2***a* Opening shape of end portion on front side in rotational direction of valve plate discharge port
T Working oil tank

The invention claimed is:

1. A hydraulic pump/motor in which a cylinder block with a plurality of cylinder bores formed around a rotation axis slides with respect to a valve plate including a high-pressure port and a low-pressure port, and which controls an amount of reciprocation of a piston in each of the cylinder bores depending on an inclination of a swash plate,

wherein a first opening shape of the high-pressure port and a second opening shape of the low-pressure port extend circumferentially on a same arc centered around the rotation axis and are annular band shapes that do not include a top dead point and a bottom dead point,

a third opening shape of a cylinder port in each of the cylinder bores extends circumferentially on a same arc where the high-pressure port and the low-pressure port are disposed, and is an annular band shape that does not communicate with the high-pressure port and the low-pressure port at least when positioned at the top dead point and the bottom dead point,

a fourth opening shape of an end portion on a front side of the cylinder port and a fifth opening shape of an end portion of a rear side of the cylinder port with reference to a rotational direction of the cylinder block are circular convex shapes,

a sixth opening shape of an end portion on a front side of the high-pressure port and a seventh opening shape of an end portion on a rear side of the high-pressure port in a rotational direction of the high-pressure port, and an eighth opening shape of an end portion on a front side of the low-pressure port in a rotational direction of the low-pressure port are circular convex shapes,

a ninth opening shape of an end portion on a rear side of the low-pressure port in the rotational direction of the low-pressure port is a circular concave shape, and

the fourth opening shape of the end portion on the front side of the cylinder port in a rotational direction of the cylinder port and the ninth opening shape of the end portion on the rear side of the low-pressure port in the rotational direction of the low-pressure port are a same shape.

2. A hydraulic pump in which a cylinder block with a plurality of cylinder bores formed around a rotation axis slides with respect to a valve plate including a high-pressure port and a low-pressure port, and which controls an amount of reciprocation of a piston in each of the cylinder bores depending on an inclination of a swash plate,

wherein a first opening shape of the high-pressure port and a second opening shape of the low-pressure port extend circumferentially on a same arc centered around the rotation axis and are an annular band shape that does not include a top dead point and a bottom dead point,

a third opening shape of a cylinder port in each of the cylinder bores extends circumferentially on the same arc where the high-pressure port and the low-pressure port are disposed, and is an annular band shape that does not communicate with the high-pressure port and the low-pressure port at the top dead point and the bottom dead point,

a fourth opening shape of an end portion on a front side of the cylinder port and a fifth opening shape of an end portion of a rear side of the cylinder port with reference to a rotational direction of the cylinder block are circular convex shapes,

a sixth opening shape of an end portion on a front side of the high-pressure port in a rotational direction of the high-pressure port is a circular concave shape,

a seventh opening shape of an end portion on a rear side of the high-pressure port in the rotational direction of the high-pressure port is a circular convex shape,

an eighth opening shape of an end portion on a front side of the low-pressure port and a ninth opening shape of an end portion of a rear side of the low-pressure port in a rotational direction of the low-pressure port are circular concave shapes,

the fourth opening shape of the end portion on the front side of the cylinder port in a rotational direction of the cylinder port and the ninth opening shape of the end portion on the rear side of the low-pressure port in the rotational direction of the low-pressure port are a same shape,

the fifth opening shape of the end portion on the rear side of the cylinder port in the rotational direction of the cylinder port, the eighth opening shape of the end portion on the front side of the low-pressure port in the rotational direction of the low-pressure port, and the sixth opening shape of the end portion on the front side of the high-pressure port in the rotational direction of the high-pressure port are a same shape,

the valve plate further includes a residual pressure release port which communicates with each of the cylinder bores after each of the cylinder bores pass the top dead point and before each of the cylinder bores communicate with the low-pressure port, and

a first opening portion of the end portion on the rear side of the low-pressure port in the rotational direction of the low-pressure port is separated from the top dead point

so as to communicate with a second opening portion of an end portion on the front side of the cylinder port in the rotational direction of the cylinder port after passing a rotation assist region where rotation of the cylinder block is assisted by a pressure oil inside each of the cylinder bores from a top dead point position of the cylinder port and a residual pressure release region where a pressure inside each of the cylinder bores is decreased by a communication between the residual pressure release port and each of the cylinder bores and

so as to shift to a suction process.

3. A hydraulic pump in which a cylinder block with a plurality of cylinder bores formed around a rotation axis slides with respect to a valve plate including a high-pressure port and a low-pressure port, and which controls an amount of reciprocation of a piston in each of the cylinder bores depending on an inclination of a swash plate,

wherein a first opening shape of the high-pressure port and a second opening shape of the low-pressure port extend circumferentially on a same arc centered around the rotation axis and are an annular band shape that does not include a top dead point and a bottom dead point,

a third opening shape of a cylinder port in each of the cylinder bores extends circumferentially on the same arc where the high-pressure port and the low-pressure port are disposed, and is an annular band shape that does not communicate with the high-pressure port and the low-pressure port at the top dead point and the bottom dead point,

a fourth opening shape of an end portion on a front side of the cylinder port and a fifth opening shape of an end portion of a rear side of the cylinder port with reference to a rotational direction of the cylinder block are circular convex shapes,

a combination of eighth and ninth opening shapes of end portions on a front side and a rear side of the low-pressure port in a rotational direction of the low-pressure port differs from a combination of sixth and seventh opening shapes of end portions on a front side and a rear side of the high-pressure port in a rotational direction of the high-pressure port,

at least one of the eighth opening shape of the end portion on the front side and the ninth opening shape of the end portion on the rear side of the low-pressure port is a circular concave shape,

when the eighth opening shape of the end portion of the front side of the low-pressure port in the rotational direction of the low-pressure port is a circular concave shape, the fifth opening shape of the end portion of the rear side of the cylinder port in a rotational direction of the cylinder port and the eighth opening shape of the end portion of the front side of the low-pressure port in the rotational direction of the low-pressure port are a same shape,

when the ninth opening shape of the end portion of the rear side of the low-pressure port in the rotational direction of the low-pressure port is a circular concave shape, the fourth opening shape of the end portion of the front side of the cylinder port in the rotational direction of the cylinder port and the ninth opening shape of the end portion of the rear side of the low-pressure port in the rotational direction of the low-pressure port are a same shape,

the valve plate further includes a residual pressure release port which communicates with each of the cylinder bores after each of the cylinder bores pass the top dead point and before each of the cylinder bores communicate with the low-pressure port, and

a first opening portion of the end portion of on the rear side of the low-pressure port in the rotational direction of the low-pressure port is separated from the top dead point

so as to communicate with a second opening portion of the end portion on the front side of the cylinder port in the rotational direction of the cylinder port after passing a rotation assist region where rotation of the cylinder block is assisted by a pressure oil inside each of the cylinder bores from a top dead point position of the cylinder port and a residual pressure release region where a pressure inside each of the cylinder bores is decreased by a communication between the residual pressure release port and each of the cylinder bores and

so as to shift to a suction process.

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